Educational Module

Title: *Basic Spectroscopy and an Evaluation of the Optical Properties of Artificially Coated Household Materials*

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Grade Level/Subject:

Physics – Optics - Spectroscopy
Grades 11 and 12
85 minute periods

Curriculum Standards & Benchmarks:

Standards
National Science Standards:

Physical Science – Interactions of Energy and Matter

- Waves, including light waves, have energy and can transfer energy when they interact with matter.

Benchmarks
AAAS Benchmarks, Project 2061
By the end of the 12th grade, students should know that

Section 3, The Nature of Technology.

3B Design and Systems: The value of any given technology may be different for different groups of people and at different points in time.

Section 4, The Physical Setting.

4E Energy Transformations: When energy of an isolated atom or molecule changes, it does so in a definite jump from one value to another, with no possible values in between. The change in energy occurs when radiation is absorbed or emitted, so the radiation also has distinct energy values. As a result, the light emitted or absorbed by separate atoms or molecules (as in a gas) can be used to identify what the substance is.

Section 8, Energy Sources and Uses.

8C Energy Sources and Use: Decisions to slow the depletion of energy sources through efficient technology can be made at many levels, from personal to national, and they always involve trade-offs of economic costs and social values.

Section 9, The Mathematical World.

9B Symbolic Relationships: Tables, graphs, and symbols are alternative ways of representing data and relationships that can be translated from one to another.

Section 11, Common Themes.

11B Constancy and Change: Graphs and equations are useful (and often equivalent) ways for depicting and analyzing patterns of change.

Section 12, Habits of Mind.

12B Computation and Estimation: Use computer spreadsheet, graphing, and database programs to assist in quantitative analysis.

12C Manipulation and Observation: Use computer for producing tables and graphs and for making spreadsheet calculations.

12D Communication Skills: Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.
12D Communication Skills: Use tables, charts, and graphs in making arguments and claims in oral and written presentations.

Overview:

In this lesson, students will review, extend, and apply their knowledge of the electromagnetic spectrum. They will learn the basic principles of spectroscopy and evaluate spectroscopic data to determine the optical properties of coated household materials: sunglasses and windows. Then they will evaluate the materials against the claims of the manufacturer. Next, they will use the data to aid in a cost-evaluation and decide which types of materials are more cost-effective and why. And finally, it is hoped that the students will effect personal changes at home by purchasing

Purpose:

The purpose of this lesson is multiple:
- To review the electromagnetic (EM) spectrum
- To appreciate and critique the diversity of ways in which man uses EM radiation
- To answer the age old questions "Why is the sky blue?" and "Why are sunsets red?"
- To understand the basic concepts of spectroscopy (light separation and detection)
- To apply the basic concepts of spectroscopy by determining the optical properties of different types of coated glass used commonly around the home
- To evaluate the optical properties of common household coatings (sunglasses and windows) against the claims of the manufacturers
- To discuss energy efficiency and energy-saving measures, including the use of low-e windows
- To determine the cost-effectiveness of the various materials tested
- To make an informed, personal decision regarding the use of specific coated materials and to capably defend that decision

Prerequisites:
Prior to starting this unit, the learner should be familiar with:
1. Basic Physical Science concepts including electromagnetic radiation
2. Algebra 1
3. Inter-converting units (e.g. um to nm)
4. Familiarity with internet use and Excel spreadsheets

Learning Objectives:
On completion of this unit, students will be able to:
1. Distinguish between the different regions of the EM spectrum, including individual colors, UV-A, B, and C, and Near IR.

- State the relationship between wavelength and energy.
- Describe how each region of the EM spectrum is significant to man.
- Distinguish between line and continuous spectra.
- Record line spectra for various types of radiation sources.
- Make qualitative identifications of metals based on simple flame spectroscopy.
- Distinguish between absorbance, scattering, transmittance, and reflectance.
- Distinguish between transparency and opacity.
- Evaluate a plot of the solar spectrum.
- Explain why the sky is blue and why sunrises & sunsets are red.
- Generate UV/Vis/NIR spectra for various household glasses using a spectrophotometer.
- Use Microsoft Excel to prepare a data spreadsheet and plot the spectrum of transmission vs. wavelength for each sample.
- Evaluate the plots and determine the optical properties of each sample (i.e. wavelength ranges of transmission).
- Evaluate the data against the claims of the manufacturer and state whether the material performs as specified.
- Perform a cost-analysis of the materials to determine which are more cost-effective.
- Make an informed, personal decision about the future use of either sunglasses or low-e windows

Key Terms:

Absorption	Continuous spectrum	Cosmic Rays	Emission
Frequency	Gamma rays	Line spectrum	Low-emissivity
Micrometer	Microwaves	Nanometer	Near-Infrared
Opaque	Radiant Energy	Radio waves	Rayleigh scattering
Reflection	Scattering	Spectrophotometer	Spectrum
Spreadsheet	Transmission	Transparent	Ultraviolet light
UV-A, B, -C	Visible light	Wavelength	X-rays
Electromagnetic Spectrum		Far Infrared	

Materials:

Various lights and appropriate power supplies (e.g. black light, fluorescent light, incandescent light)
Lamps of various gaseous elements and appropriate power supply
Simple spectroscope (e.g. goofy goggles)
Salts of various metals

Spectroscopic data from: a sample of “plain” glass, lenses from 2 or more different types of sunglasses (cheap and expensive), a sample of coated window glass or window film (e.g. house, car)
Computer with Microsoft Excel (or equivalent) software, and a color printer

Background Preparation (Days 1, 2):

Part One – The EM Spectrum (Attachment 1) (ETC = 40 min.)

1. Students individually use the Internet to help them prepare a chart of the EM spectrum.

Part Two – Electron Transitions & Spectroscopy (Attachment 2) (ETC = 45 min.)

1. Students individually take some notes, including diagrams of electron energy level transitions.
2. Students work in pairs to use a power supply, several lamps, and a simple spectroscope to draw the line spectra emitted by various sources.

Part Three – Flame Test Mini-Lab (Attachment 3) (ETC = 85 min.)

1. Students work in pairs to perform mini-lab; students do individual write-ups.
2. Students participate in a class discussion about their flame-test lab results.

Main Activities (Days 3,4):

Part One – The Solar Spectrum (Attachment 4) (ETC = 30 min.)

1. Students individually define several key terms.
2. Students work in pairs use a plot (provided) of the solar spectrum as well as absorption spectra of water, CO2, and ozone to analyze: a) the radiation generated by the sun and b) solar radiation absorbed by the atmosphere.

Part Two – Spectroscopy Data Manipulation (Attachment 5) (ETC = 85 min)

1. Students receive spectroscopic data for various household materials and individually use Microsoft Excel to create a spreadsheet for the data.
2. Students work in pairs to evaluate the data and decide which spectra are associated with which materials.

Part Three – Class Discussion (Wrap-up) (ETC = 30 min)

1. Students share the results of their analysis and discuss the cost-effectiveness of the different materials, and life-decisions they can make using this information.

The EM Spectrum

Name ________________

An Internet Assignment (10 points)

On the back of this page, prepare a chart of the electromagnetic spectrum. The chart should include the following:

- each type of radiation (cosmic; gamma ray; x-ray; ultraviolet including UV-A, UV-B, and UV-C; visible including violet, indigo, blue, green, yellow, orange, and red; infrared including near and far; microwave; radio waves including AM, FM, and TV)
- the wavelength range for that type of radiation including the units (use nanometers (nm) for visible and UV)
- the frequency range for that type of radiation (use Hz)
- the impact on man (uses and/or hazards) for that type of radiation

Your effort will be evaluated on completeness of information and neatness.

 Name_______________

Introduction

The aufbau principle states that electrons in an atom occupy the ____________ energy levels first. When all the electrons in an atom occupy the lowest energy levels, the atom is said to be in the _____________ ____________.

Occasionally, atoms will ______________ energy (e.g. from heat or electricity). When this happens, an electron may move from a lower energy level to a higher one, thereby going to an __________________ _______________:

Sometimes, there is enough energy to ____________ the electron completely. This process of _____________ an electron is called _____________________ because an _________ is formed:

Atoms in the excited state are ________________ and want to _____________ back to the ground state. This happens when an electron shifts from a higher energy level to a vacancy in a _______________ energy level. When this relaxation occurs, ______________________ is emitted, often as ___________:

(over)

When an electron changes from one level to another, it is said to have undergone a __________________. Because the energy between one level and another is a specific amount (i.e. __________________), only a *certain amount* of energy is absorbed or emitted. These energy packets are known as ________________ and travel like ______________.

The ___________________ of energy absorbed or emitted depends on the energy of the photons. The ______________ the energy, the ______________ the wavelength. Sometimes, energy emitted is visible as ____________. The ______________ of the light depends on the wavelength/energy of the photon.

The study of light and electron transitions is known as ____________________. Each element has a unique number of protons and electrons, so each element emits a unique _________________.

Continuous spectrum: ____
____

Line spectrum: ____
____

Spectroscopy: Atomic Emission Spectra

		R	O	Y	G	B	I	V	
Wavelength=>									

Element	**Color**	**← S p e c t r u m →**
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State the relationship between the element color and it's bright-line spectrum:

<u>Mini-Lab</u> - Flame Tests

Introduction - When heated, each element emits a characteristic pattern of light energies which can be useful for identifying the element. A *flame test* is a method of identifying an element by heating it in the flame of a Bunsen burner to produce the characteristic color.

Abstract - Colors emitted by various elemental salts are observed and recorded. Unknown samples will be tested for element identification based on a flame test. The flame test will then be evaluated as a method of detection of elements.

Materials: Safety goggles; Bunsen burner; stainless steel scoopula; small beaker of distilled water; samples of various elemental salts (chlorides or nitrates) such as aluminum, barium, calcium, copper, lithium, potassium, sodium, strontium, etc.; "unknown" elemental salts.

Procedure:

1. Prepare a data table with four columns: "Compound Name"; "Molecular Formula"; "Appearance"; and "Flame Color".
2. Obtain a small sample of salt. Record the name of the compound and it's molecular formula. Record its physical appearance according to the following: particle size - fine, medium or coarse; particle color - white, off-white, yellow, etc; particle shape: uniform or irregular; particle texture - powder or crystals (e.g. 'fine white powder" or "coarse yellow irregular shaped crystals" etc.).
3. Put on goggles and carefully light burner. Adjust the air and gas flow so that the outer cone of the flame is dark blue and the inner cone is light blue.
4. Clean the scoopula by dipping it in the distilled water and then heating it in the flame. The scoopula is clean when no more color appears.
5. Dip the clean scoopula into the distilled water again. Then dip it into the salt, being sure some of the compound sticks to the scoopula when it is withdrawn.
6. Place the part of the scoopula that has the salt sticking to it into the lower portion of the flame. Record the color of flame produced: use colors (or combinations) such as white, gold, red, crimson, orange, yellow, green, blue, indigo, violet and descriptors such as "bright" or "deep" or "pale" (e.g. "deep red" or "pale violet").
7. Repeat steps 2 through 6 with each known salt.
8. Create a second data table that has *five* columns: "Unknown" "Appearance" "Prediction Based on Appearance Alone" "Flame Color" and "Prediction Based on Appearance & Flame Color"
9. Obtain a small sample of an unknown. (Each 'unknown' is one of 'knowns'.) Record the name of the unknown in the 'Unknown' column.
10. Make/record observations about the physical appearance of the unknown. Record appropriately.

(over)

11. Based on those observations of physical appearance, *predict* which element the unknown salt contains. Record your prediction in the 'Prediction Based on Appearance alone' column.
12. Perform a flame test for the unknown. Record the flame color appropriately.
13. Now, based on *both* the physical appearance *and* the flame test, make a final prediction for the unknown, and record in the "Prediction Based on Appearance & Flame Color" column.
14. Repeat steps 9-13 for other unknowns.
15. Clean off the scoopula one last time and then turn off the Bunsen burner. Clean up the work area.

Predictions
Using *complete sentences*, state which compound you think each unknown is, for example: I predict Unknown A is Copper Chloride.

Discussion
Respond to the following using *complete sentences*.
1. Did your predictions about the unknowns change once you performed the flame test? Why or why not?
2. Which elements do you believe are *most* easily identified? Why?
3. Which elements do you believe are *least* easily identified? Why?
4. Discuss how useful you think flame tests are for detecting elements, and why you think that.
5. Fireworks are made from metal salts, which give them their color on exploding. For each of the following firework colors, state which element you think is used:

    bright green
    deep red
    blue
    yellow

A good web site about fireworks is: http://www.pbs.org/wgbh/nova/kaboom/

The Solar Spectrum

Name ________________

1. Use available resources to define the following terms.

   Absorption –

   Blackbody radiation -

   Emission –

   Opaque –

   Reflectance -

   Scattering -

   Rayleigh scattering -

   Transmittance –

   Transparent –

2. Study the plot below and answer the questions on the back:

a. Over what wavelength range(s) does the sun mostly emit radiation?

b. In which range(s) is the sun's radiation the most intense?

c. Which range(s) of the electromagnetic spectrum does this correlate with?

3. Now study the plots below and answer the following questions.

- Convert the wavelengths from microns to nm and write the nm scale below the um scale.

- List the primary wavelength ranges of absorbance for:

  Water: ____________ Carbon dioxide: ____________ Ozone: __________

- Water, carbon dioxide, and ozone are all present in the atmosphere and will absorb radiation from the sun. In the space below, draw a *combined* plot of transmittance vs. wavelength for the atmosphere (as if they were overlain).

- List the regions of the atmosphere that are *transparent*.

- Write a paragraph explaining why the sky is blue.

- Write a paragraph explaining why sunrises and sunsets are often red.

Spectroscopy and Glass Coatings

Name ________________

An Excel Spreadsheet Assignment

ABSTRACT

Scientists will use the spectroscopic data provided to generate plots of Transmittance vs. Wavelength for 5 different "unknown" types of common coated glass. The students will then evaluate the spectra to determine the optical properties and draw conclusions about which glass is which.

PROCEDURE

Use the disk provided by your instructor.

Log on to the computer, enter "Excel".

Choose one of the five data files to load.

Generate a plot of the data.

Repeat for the remaining four samples.

ANALYSIS

1. What are the wavelength ranges (in nm) for the following regions:
   UV –
   VIS –
   IR -
2. Which sample(s) transmit UV?

3. Which sample(s) transmit IR?

4. Which sample(s) best transmit VIS?

5. The five samples are listed below. Match them with the spectra:
   _____ Plain glass
   _____ McKids sunglasses ($4.97 @ Wal-Mart)
   _____ UVEX smoked lens sunglasses ($120.00 @ fine stores everywhere)
   _____ UVEX orange lens sunglasses ($120.00 @ fine stores everywhere)
   _____ Heat reflective window-film ($14.95 @ hardware stores)